



Exploring Elementary Students' Invention Ingenuity in Science Labs

İlköğretim Öğrencilerinin Fen Derslerinde Buluş Yaratıcılığının Keşfedilmesi

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Abstract. Invention is one of the strongest forces that lead to human civilization. Without a clear picture and scientific understanding of invention, it can hardly be any continuity of the past, present, or future. This study carried out in Ma'an, a poor-environment area of Southern Governorate in Jordan, with 50 ninth-grade students: 25 males and 25 females aged 15 years old, has one aim which is to explore ninth-grade students' invention ingenuity in science labs. Fifty ninth-grade students from two schools of Ma'an directorates of education were chosen randomly to participate in inventing Products to solve five problems asked them in science labs. A mix of qualitative and quantitative methodology was used to answer the study questions. Results of the study showed the students invented good products for the solving problems, teachers appreciated the Invention in Science Labs framework as an instructional model, and students valued this kind of learning experience. Recommendations were included in this study.

Keywords: Physics, Science labs, Creativity, Invention, Innovation

Öz. Buluş insan medeniyetinin devamını sağlayan en güçlü etkilere birisidir. Buluşun bilimsel anlamı ve net bir resmi olmadan, geçmiş, bugün ve geleceğin devamlılığı olamaz. Ürdün'de bulunan Güney Valiliğinin yoksul bir çevresi olan Ma'an'da 50 dokuzuncu sınıf öğrencisi, 25 erkek ve 25 kadın ile yürütülen bu çalışma, öğrencilerinin fen laboratuvarlarında buluş yaratıcılıklarını keşfetmeyi amaçlamaktadır. Ma'an eğitim müdürlüklerine bağlı iki okuldan elli öğrenci kendilerine sorulan beş problemi çözmek için fen laboratuvarlarında ürünler icat etmek üzere rasgele olarak çalışmaya katılmışlardır. Araştırma sorusuna cevap vermek için nitel ve nicel araştırma yöntemleri birlikte kullanılmıştır. Çalışmanın sonuçları öğrencilerin problemlerin çözümüne yönelik iyi buluşlar icat ettiklerini, öğretmenlerin fen laboratuvarlarında buluş çerçevesinden memnun olduklarını ve öğrencilerin bu tür öğrenme deneyimine değer verdiklerini göstermiştir. Öneriler çalışmada yer almaktadır.

Anahtar kelimeler: Fizik, Fizik laboratuvarları, Yaratıcılık, Buluş, Yenilik

INTRODUCTION

Interest in creativity, invention and innovation as an area of educational research began in the mid of the 20th century. Bloom's taxonomy has been changed as creativity became at the top of it. Scholars' researches on creativity have had an impact on educational curriculum elements (Objectives, Content, Methodologies and Evaluation) as Torrance (1983) pointed. Despite the fact that creativity, invention and innovation are orbiting in the same theoretical epistemology, we have to distinguish between those concepts when reflecting them within learning and teaching environment to assure the inquired activities of the proposed invention framework in this study. Creativity ultimately involves the production of original, potentially workable, solutions to novel, ill-defined problems of relatively high complexity (Besemer & O'Quin, 1999; Lubart, 2001) where in simple words theoretical thinking of a new idea as the researchers define it. Invention is the first occurrence of an idea for a new product or process as Fagerberg (2004) defines it, which can refer to practical thinking; while innovation is the first commercialization of the idea (Fagerberg, 2004). We think creativity is just an idea, invention is thinking practical and empirical production, and innovation is commercialization of the idea or the product as Fagerberg (2004) pointed.

Background of the Study

When thinking about inventors, the image of great inventors like Edison is formed in our minds, as we adults are involved in producing something unique and useful. For others, the image could be that of a star movie. Young inventors are out of the image because everything in life has been made by the adults. We are behind the idea that if someone creates a product without knowing whether it has existed earlier or not, then the product is an invention made by an inventor. In the early 1980s', the United States Patent Office committed to a comprehensive effort to introduce thinking at all levels of school curricula (Colangelo, Assouline, Croft, Baldus, & Ihrig, 2003).

Currently, disciplines are being taught by invention approach. Several studies findings pointed to the importance of using invention as an instructional framework considering that educational invention helps students achieve content objectives effectively (Westberg, 1996; Rule et al, 2009; Wongkraso, Sitti & Piyakun, 2013). Teaching students how to invent provides them with an opportunity to identify how all the parts of a complex system interact and depend upon each other (Martinez & Stager, 2013). Many previous studies have examined and surveyed the effectiveness of the approaches of teaching to invent and students' abilities to invent (Wongkraso, Sitti & Piyakun, 2013). Other studies underlined the scientific process skill programs or thinking skills (Kuehn & Krockner, 1986; Westberg, 1996; Rul et al., 2009; Lee et al., 2014). Those programs showed limited success in improving invention abilities, while students aged fifteen developed their inventive abilities during science courses by using invention learning approach (Wongkraso, Sitti & Piyakun, 2015).

At college level, Daly et al (2016) surveyed 450 university students in nineteen different courses experiences focusing on students, perceptions of their educational experiences, the perceived contributions of specific pedagogical components, and their assessment of courses' impact on their own creative development. The brief review of relevant studies and literature on teaching by invention shows the importance of teaching by invention and the need of more research about different approaches and instructional models for teaching by invention, since no studies have been found to use this approach of teaching within science labs according to the survey conducted by the researchers.

In the Arab countries, there is a little opportunity for youths and even adults to commercialize their invention; the main reason is simply that Arab countries are not industrial countries, but rather consumers. Thus, inventors immigrate or sell their inventions to the first world countries, beside the fact of little funds to expend for the benefit of scientific researches. So, it is hard to believe that curricula based on creativity and inventions have any obvious attention within school context. We think that before having such invention programs like Invent Iowa; we must explore our school students' abilities and ingenuity of inventing.

Historically, little attention has been given for invention within education, while a narrow view of invention as experiments done in science labs. On the other hand, researches conducted over the time out of the Arab world but within classrooms or science labs context for training or measuring students believes, invention training or design education (Westerberg, 1996; Schauble, Klopfer, & Raghavan, 1991; Pace & Larson, 1992; DuBois & Keller, 2016; Fleith, Renzulli & Wetberg, 2002; Meyer, & Lederman, 2013).

Conceptualization of Invention

Meyer and Lederman (2013) explored the pedagogy of ingenuity in science classrooms. They used a framework to guide the analysis of each of the activities the teachers shared on the questionnaire and observed by the researchers. This facilitates the researchers' assessment of whether each activity had the potential to permit fluency, flexibility, and thus potential for responses that are significantly different across a group of students (original) as shown in Figure1:

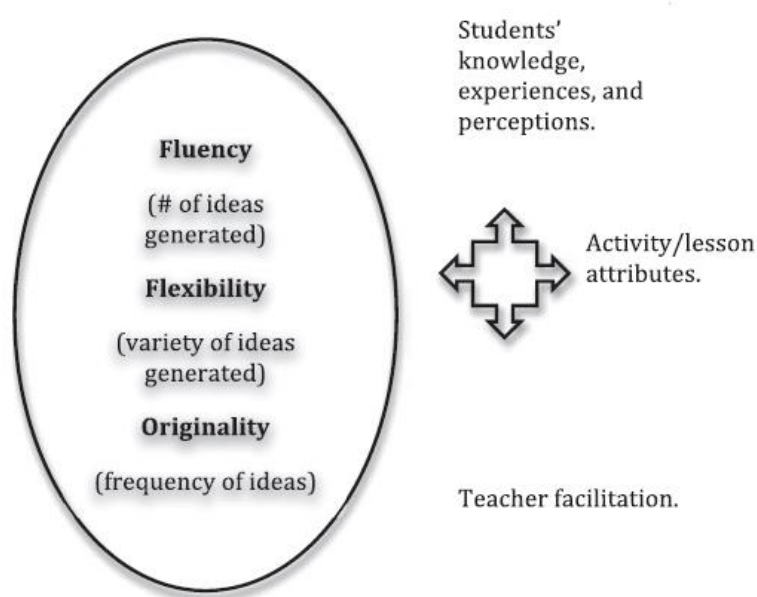


FIGURE 1. *Creative thinking in the science classroom analysis framework (Meyer & Lederman, 2013, p403)*

Bostrom and Nagasundaram (1998) provided suggestions for future research in this sub-field for four key creativity factors, where they classify their work in terms of whether it addresses the creative Person, Product and Press as adapted from Fellers and Bostrom (1993), as shown in Figure2:

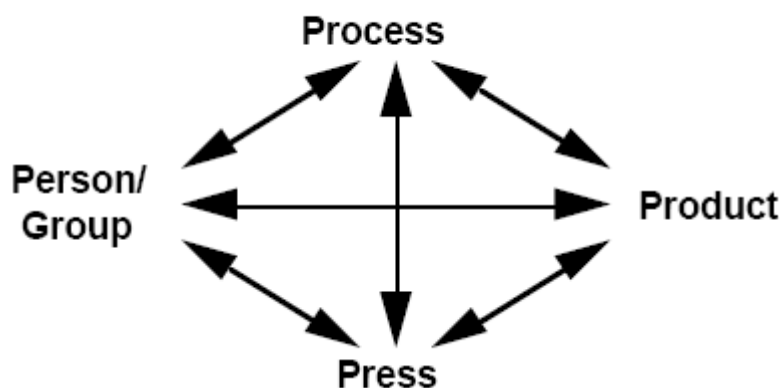


FIGURE 2. *Sub-field for four key creativity factors (Bostrom & Nagasundaram, 1998, p391)*

Invention in Science Labs (ISL) framework

The proposed ISL framework in this study conceptualizes invention within science labs by four elements representing phases of reaching inventions in a group context: Theoretical thinking: this phase concentrates on intellectual thinking to generate ideas (fluency), variety of ideas generated (flexibility) and frequency of ideas (originality) about the proposed study through group brain storming to give proper solutions and discuss the most appropriate and applicable ones. Solution: this phase concentrates on evaluating the solutions and discusses the most appropriate and applicable ones after studying the available materials. Materials: this phase gives the students an opportunity to think practically for producing the product, context: the phase of team work to produce the product within the environment of science lab to transform the selected proper solution into a concrete product (invention), with respect to instructional methodologies used, as the four elements shown in Figure3:

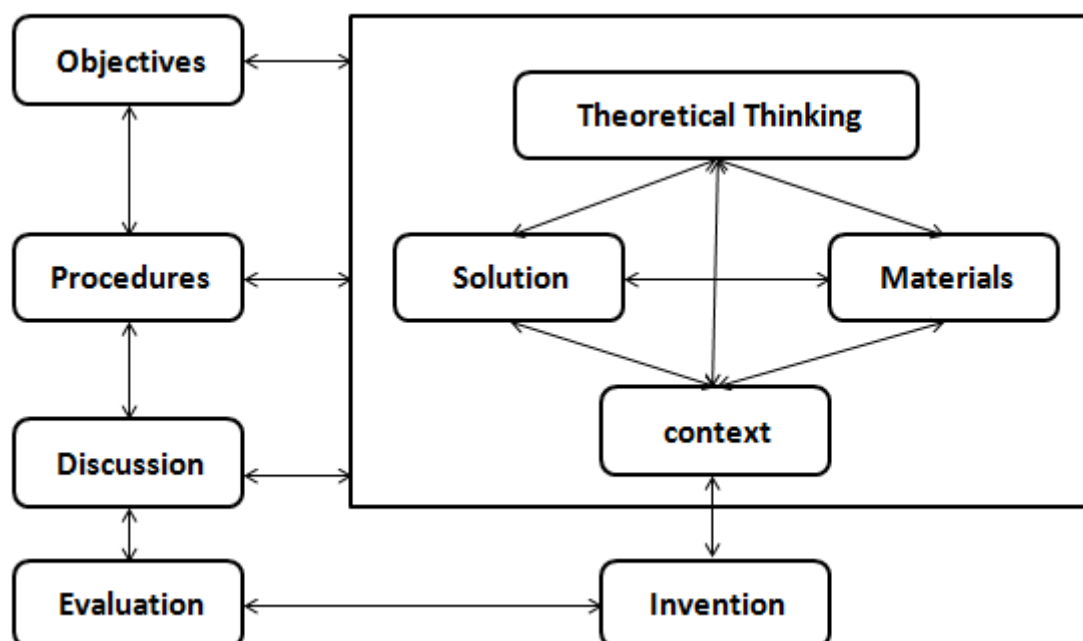


FIGURE 3. ISL framework

Teacher presents objectives to the students (a problem to be solved) where they must generate intellectual ideas that works as a solution for the main problem. Teacher administrates the procedures that students should follow within a group and team work, while discussion takes place under teachers' supervision, and evaluating all of the process and product that invented.

Purpose of the Study

The purpose of this study is to explore ninth-grade students' invention ingenuity in science labs environment. To achieve the goal of the study, the study was conducted to answer the following questions:

1. How do elementary students in Jordan perceive learning by invention in science labs?
2. What is the invention ingenuity level of elementary students in Jordan?
3. Does invention ingenuity of elementary students in Jordan differ according to their gender?

Significance of the Study

The findings of the study will enable policymakers, school administrators and teachers to have a good background of how teaching and learning should be. The findings will give curriculum designers concrete ideas on areas for improvement, such as curriculum development,

comprehensibility of texts and simplified instructions. Also, it will provide useful information for future research work in the areas of using invention as a methodology of teaching science at the elementary school level.

METHOD

The primary aim of this study is to examine and explore elementary students' invention ingenuity in science labs environment. In order to answer the proposed research questions, the qualitative and descriptive quantitative research methodologies were used. The qualitative methodology is appropriate an approach to exploring and understanding the meaning individuals or groups ascribe to a social or human problem (Creswell, 2014). The quantitative approach where used to measure students' abilities to invent by solving specific problems they faced with where grounded theory design can be applied (Creswell, 2014).

The concurrent nested design was used in this study, while qualitative design was used to answer the first question and the quantitative method was used to answer questions two and three, hence the study is a pre-experimental design as a one-shot case (Creswell, 2014).

Participants

The participants of the study consisted of (50) ninth- grade students, 25 males and 25 females from two schools in Ma'an Directorate of Education in Jordan. The participants were around (15) years old. The administrations of the two schools approved conducting the study.

Ethics

The study as a whole was approved by the Directorate of Education for the Governorate of Ma'an, in addition approved by Al-Hussein Bin Talal University Research Ethics Committee at the Faculty of Education.

Data collection methods

Data for the first question obtained from different sources including documents (teachers' lesson preparation), observations (field exploring), and interviews were analyzed in a way to protect the confidentiality of all the participants by giving them pseudonyms. The interviews data of the teachers only recorded under the permission of the participants then written in hard copy form, the researchers gave the hard copies of the interviews to booth of teachers in order to assure the words recorded have the same meaning as spoken as phonics of Arabic language may give different meaning of the same written words. Themes where categorized according the participants' phrases, sentences and meanings which were symmetric among them and under each question theme.

Data obtained from the product evaluation card were analyzed using SPSS. One sample t-test was maintained to answer the second question; seven out of the total score (10) is the crucial score. Two sample t-test were used to answer the third question.

Instrument

The study used two instruments: the first instrument was a semi structured interview with open ended questions for both teachers and students to reflect their perceptions of ISL by answering the following questions:

1. Describe your participation in invention activities?
2. Can the invention be commercialized?
3. If you wanted to give recommendations for your peers about invention activities, what would you say?

The second instrument used in this study was a product evaluation card scaled 1-10 scores for each of its items (Appendix A). The production card consisted of 9 items: Safety, Cost of Materials, Easiness of use, Power saving, Efficiency, Community needs, Novelty, Applicability, and consistency with religion hence people do not change the perceived connection between religion and science, even if they were in a scientific course which integrated activities explicitly addressing the nature of science (Aflalo, 2018).

The product evaluation card was validated through four referees from the department of curriculum and teaching at Al-Hussein Bin Talal University, where Dependability which reflected reliability, depends on instrument consistency, predictability, stability, or accuracy. The reliability (0.90) was calculated by using Holsti's formula through evaluating a product by two teachers. The items of the product evaluation card consisted of product, consistency with religion, applicability, novelty, community needs, efficiency, power saving, easiness of use, cost of materials and safety.

Context of The study

After taking approvals from to conduct the study, the researchers held a workshop for the two teachers to demonstrate the ISL mechanism, while all needed materials where provided in the science lab. The workshop concentrated on how to administrate interactivity and direct students to accomplish products. Davies et al (2013) emphasized the necessity of creating a respectful relationship between teachers and learners and providing a rich environment while learning how to invent. Teachers started with objectives where the students will be able to give theoretical ideas and invent products to solve the following problems:

1. A Main Gate of the school that closes by gravity force after opening it,
2. A doorbell for a deaf person,
3. A doorbell for a deaf and blind person,
4. A toy car that uses static force, and
5. A toothbrush that runs by electricity for a handicapped person.

The students were divided into ten groups; five groups for male students and five groups for females; five students for each group. Each group was involved in 4 a one-hour science lab workshop per week for four weeks, in order to solve one problem for each group. The problems were presented to the students. The students were asked to brainstorm solutions for each problem by giving theoretical ideas of suitable invention by working in a worksheet (Appendix B). The worksheet benefited from Invent Iowa Rubric instructional invention guide, where some questions reformed into steps such as: stating the problem, invention efficiency invention workable, well constructing prototype, and satisfying the need. Teachers followed brain storming strategy and eliminated the inapplicable ideas after a discussion with each group. They made improvements on the suitable theoretical ideas of the invention. Materials where provided for the students, in order to convert their theoretical ideas into a product.

RESULTS and DISCUSSION

The data collected in this study were analyzed qualitatively to answer the first question, and organized into binders with the same theme, while documents were compared with teachers' interviews. The field exploring was detected to stand on science labs and students while involving in activities, researchers took pictures for materials used and students working in science lab:



FIGURE 4 *Some materials and students' activities*

Research Question 1

Research Question 1: How do elementary students and teachers in Jordan perceive learning by invention in science labs?

To examine Research Question 1, qualitative approach was used to explore the participants' perceptions of ISL. They were asked to answer the following questions:

1. Describe your participation in invention activities?
2. Can the invention be commercialized?
3. If you wanted to give recommendations for your peers about invention activities, what would you say?

During the researchers' visits to the students while they were working in the laboratories, the following observations were noted:

- The students suggested alternative solutions to problems that are not within the expectations of the researchers.
- They enjoyed their work and asked for more problems to be presented for them to work on.
- They were able to practice and develop their skills during work.
- They were able to suggest other life problems and showed desire to design models and solutions for those problems.
- They expressed dissatisfaction toward their present curriculum because it doesn't motivate them to learn through work and innovation.
- The achievements and performance of females were better than those of males.
- Some low-achieving students showed that they excelled the work and performance of some high-achieving students.

The qualitative findings provided further insight about aspects related to the learning by invention in science labs framework that influenced how students and teachers perceive learning by invention in science labs. Data analyses generated three core themes: (a) the implementation of the ISL, (b) the community benefits, and (c) the educational value. Table 1 summarizes the students/teachers' responses according to the three categories:

Table 1. *Summary of students' interviews*

Themes	Categories	Responses	Students, N=50	%	Teachers, N=2	%
Implementation of ISL	Invention activities	Gaining attention	50	100	2	100
		Self confidence	50	100	2	100
		Brain storming	40	80		100
		Social involvement	46	92	2	100

Community benefits	Invention commercializing	Motivation	50	100	2	100
		Parents attention	23	46	2	100
		Marketing	41	82	2	100
		Environment exploring	50	100	2	100
Educational Value	Recommendation for Peers	Implication of product	36	72	2	100
		Circulation	50	100	2	100
		Value of activities	48	96	2	100

Teachers' and students' description of their participation in invention activities: Despite the fact that all the participants participated in learning situations in science labs at their schools, but not in an invention context, while the teachers are the same, the ISL is beyond an experiment to proceed in a science lab, for instant, male students' teacher stated: "ISL helps teachers to change their acts when thinking about teaching plan, even teachers' enrolments will be changed while students involved in activities it became more easier to capture students attention". The teachers confirmed that ISL shifted the way of presenting content in a manner of an interactive situation based on dialogue and brainstorming, while female students' teacher confirmed the importance of changing the way she interacts within learning/teaching situation, she pointed to "less talk and chalk". The two teachers agreed that their participation is very effective for their careers development and students as an interactive, mind respect and learning as they stated "Bee-Hive", where students had an opportunity to identify how all the parts of a complex system interacted and depended upon each other as Martinez and Stager (2013) mentioned.

When students were asked how they describe their participation in invention activities, both male and female students showed a high positive esteem and self-confidence to share every details of their experience, one of the students revealed his parents contribution to visit the school and to donate some extra materials that may help producing those inventions, 40 of the students used the words "I used my brain", 46 students pointed the benefits of social interaction and enabling students to develop their oral skills and communicating scientifically with each other as what of the male student said "now I can know how my friend think, he is now my good best friend". The most agreeable statement with (100%) between all the participants is "it was joyful", 23 calls were received by teachers from students' parents about continuity of such a workshop as they stated.

Commercializing students' inventions: this question refers to the way that students perceive the impotency of their products for the benefit of their own community. All of the 50 students asking whether some of their inventions are exist in the real world except the tooth brush invention, one of male students stated: "we have been taught physics, but we have never been taught its' indirect implications". Approximately 41 students confirmed that those products that they invent –whether if they are existed or not- can be commercialized after reducing its' cost.

Recommendations for peers: this question reflected both teachers' and students' educational value of invention in the activities they have participated in. The teachers confirmed that they will organize a workshop for their colleagues to apply this strategy of teaching. One teacher said: "others have to know about this exiting experience"; the other said: "I have already started planning with our school principal to organize workshops for my colleagues". The students showed their capabilities as they were chosen for those activities. They said that other students should have the same opportunity. All the 50 students confirmed circulating such a way of understanding science in other classes, one of the student stated: "other students should know", while 48 students confirmed the value of those activities as one of the students stated: "learning should be like this way".

Summary of Question 1: All the participants described their participation in invention activities as an amusable and valuable experience where they understand science in a different

and applicable way. Both of teachers and students started to navigate internet and other resources about science applications in the real world, this is an indicator of value appreciation and how to an effective in your community by solving problems people face, which means how to commercial your ideas, products and inventions. Teachers felt the importance of using different approaches that direct their students to be more active within classrooms and find this approach is a very effective for their career also, while both of teachers recommended this approach to their colleagues.

Teachers stated that this experience should be spread to other teachers confirming Goodnough and Murphy (2017) finding which is expansion of teachers' community served as a catalyst in their adoption of new tools. The overall conclusion indicated to the usefulness of the proposed model (ISL) in this study, where different learning models can change spiritual and social attitudes of students with different academic abilities (Bachtiar, Corebima, & Indriwati, 2018). All pictures and videos taken while students enrolled in activities and their invention products are available at:

<https://drive.google.com/drive/folders/0BxsYevnf9CmjQTjDVnJJM3Vocjg?usp=sharing>

Research Question 2

Research Question 2: What is the invention ingenuity level of elementary students on Jordan?

To examine Research Question 2, quantitative approach was used to examine the invention ingenuity level of ninth graders students. Researchers and teachers evaluated the products to assess those inventions ingenuity level at the crucial score 7 out of 10 derived out of ninth grade students' average in the both schools. Means and standard deviation were calculated as in table2:

Table 2. Means & SD of invention ingenuity

Invention Ingenuity	Male Mean	SD	Female Mean	SD	Total Mean	SD
consistency with religion	10	-	10	-	10	-
applicability	8.4	0.89	7.8	0.84	8.1	0.88
novelty	8	1	7.2	2.05	7.6	1.58
community needs	8	1	7	1.58	7.5	1.35
efficiency	8.6	0.55	8.2	0.84	8.4	0.7
power saving	8.2	1.1	8.2	0.45	8.2	0.79
easiness of use	8.8	0.45	8.4	0.55	8.6	0.52
cost of materials	8.8	0.45	8.2	0.45	8.5	0.53
safety	8.8	0.45	8.2	0.45	8.5	0.53
Total	8.62	0.55	8.13	0.64	8.38	0.62

To examine the obvious scores for the total score of inventions ingenuity level of ninth graders students at the crucial score 7, one sample t-test used for the total score (M=8.38, SD=0.62) at $\alpha \leq 0.05$ with df=9 representing the 10 groups of the 50 students, where calculated $t=7.025$ was significant. Therefore, the invention ingenuity level of ninth graders students is above the level 7 out of 10 which can be considered a good level of ingenuity according the previous average of the ninth grade students' achievement for both schools.

Results of Question 2 are very constant with the findings of Wongkraso, Sitti and Piyakun (2015), while the Invention within science lab model can be helpful and useful as Bostrom and Nagasundaram (1998) of sub-field for four key creativity factors they suggested beside Meyer & Lederman (2013) framework of creative thinking in the science classroom analysis framework.

Research Question 3

Research Question 3: Does invention ingenuity of elementary students in Jordan differ according to their gender?

To answer Research Question 3, quantitative approach was used to examine the participants' invention products. When looking at students' invented products, it can be concluded that all products are ranged between 7.44-9.11 with total average 8.38 as shown in table 3:

Table 3. Means & SD of products

Invention Ingenuity	Male Mean	SD	Female Mean	SD	Total Mean	SD
A Main Gate of the school that closes by gravity force after opening it	9.11	0.33	8.33	0.71	8.72	0.67
A doorbell for a deaf person	8.44	0.88	8.33	0.87	8.39	0.85
A doorbell for a deaf and blind person	7.78	0.97	7.56	1.51	7.67	1.24
A toy car that uses static force	8.67	1.00	7.44	1.59	8.06	1.43
A toothbrush that runs by electricity for a handicapped person	9.11	0.33	9.00	0.50	9.06	0.42
Total	8.62	0.55	8.13	0.64	8.38	0.62

Independent Sample t-test where used to determine the significance differences between male and female means. Where $t=2.178$, $df=88$ was significant at $\alpha \leq 0.05$ for the benefit of male students ($M=8.62$, $SD=0.55$). This finding is similarly constant with Kuehn and Krockover (1986) findings of the existence of a relationship between fifth and ninth graders students' inventive abilities and creativity.

Even their a significant differences between Male/Female invention products, but both of them can be defined in the same level, while male students perceive more handy work in real life more than female students.

CONCLUSION

The main aim addressed in this study was to explore ninth- grade students' invention ingenuity in science labs environment to examine the use of the proposed Invention in Sciences Labs framework. The qualitative data revealed that participants gain a new view of theoretical applications in real world and found that this approach of learning is more effective and valuable for them in understanding knowledge and its application in life. The quantitative data revealed that participants had significant understanding of reflecting their ideas into a concrete form as inventing solutions for a problem they faced. Those findings are consistent with previous studies (Shlesinger, 1980; Westberg, 1996; Roll, 2009; Wongkraso, Sitti & Piyakun., 2015). The scores of students' invention ingenuity were highly significant. This was because the students had the opportunity to focus on designing the invention, producing it and examining possibilities of commercializing their own inventions.

The study revealed significant understanding of how teachers and students perceive ISL experience with the hope of more understanding the change that occurs when teachers and students involve in such activities, and all participants interact with ISL and understand its benefits for teaching and learning. The participants did not have any pre-experience in learning epistemology by inventing products to solve real life problems. Teachers can changed their approaches of instruction when the have the opportunity to practice it, while students can be more active and enjoy learning. Based on the findings of this study and the related conclusions, the researchers' recommendations for the Ministry of Education in general to conduct competitions between students to invent products like Invent Iowa and the directorate of education in Ma'an are related to the following major aspects: first, training teachers on instructional designing skills based on ISL framework; second, providing more technical support

and more attention to science labs by providing more materials in science labs and employing full time technician for each lab; third, designing curricula that is compatible with the teaching approach based on invention and discovery and that the content is directed to the real problems of students and society; and finally, organizing in-service training programs for the teachers to develop creative thinking and invention and discovery skills.

For further studies, the researchers recommend a larger-scale replicate study with a larger number of participants, and with other disciplines such as Art. Quantitative/mixed-method research studies should be conducted to explore the impact of using ISL on the students' achievement compared with traditional environment.

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Appendix A Product Evolution Card

Invention Ingenuity	Score (1 – 10)								Mean
	Consistency with religion	Applicability	Novelty	Community needs	Efficiency	Power saving	Easiness of use	Cost of materials	Safety
A Main Gate of the school that closes by gravity force after opening it									
A doorbell for a deaf person									
A doorbell for a deaf and blind person									
A toy car that uses static force									
A toothbrush that runs by electricity for a handicapped person									
Total									

Appendix B Working Sheet (Questions of an Example of A problem)

First problem: Help a blind/deaf person to know if someone at the door of his home?

Tools/Materials available: Electrical kill key, Electrical lamb, Remote control toy car, Wristwatch, Bill hanged inside a room.

Describe the above tools and materials functions?

Discuss the relationship between these tools?

What is the relationship between these tools and the addressed Problem?

Can those tools be helpful to solve the problem?

Address solutions to help the blind/deaf person by using these tools and materials?

What is the most suitable solution?

What are the implementation procedures?

Suggest how this product can be developed?

Suggest how this product can be developed commercially?